Very Long Term Oxidation of Ti-48Al-2Cr-2Nb at 704 °C in Air

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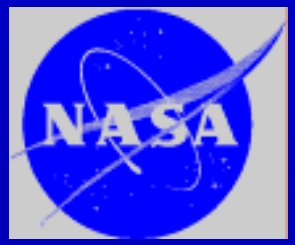
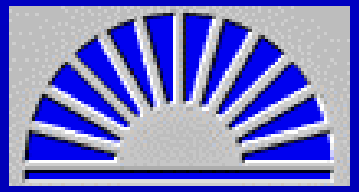
Orlando, Florida



Lewis Research Center



Case Western Reserve University

Introduction

- Are γ-alloys sufficiently oxidation resistant at realistic use temperatures (i.e. ~700 ºC) for long term exposures?
- What type of scales are formed at these temperatures?
- Is there substantial interstitial penetration (O, N) as in the case of α_2 - orthorhombic alloys?

Oxidation Of Ti-Al Based alloys

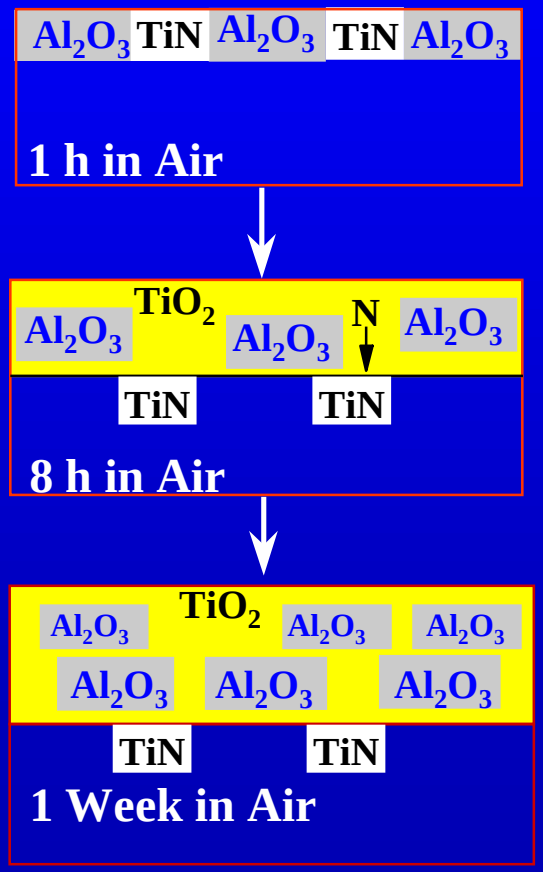
- **Key is to Establish Continuous Alumina Scale**
- Alumina: Low Growth Rate, Stability Advantage
- Titania: Rapid Growth Rate, Less Stable

The Nitrogen Effect

Gamma Forms Continuous Alumina in Pure Oxygen but Not in Air

(Choudhury et al., 1976)

- Portions of Rakowski et al. (1995) Mechanism: Binary TiAl, 800°C-900°C, Air



- **Nitride formation must also be considered**

Experimental

Alloy

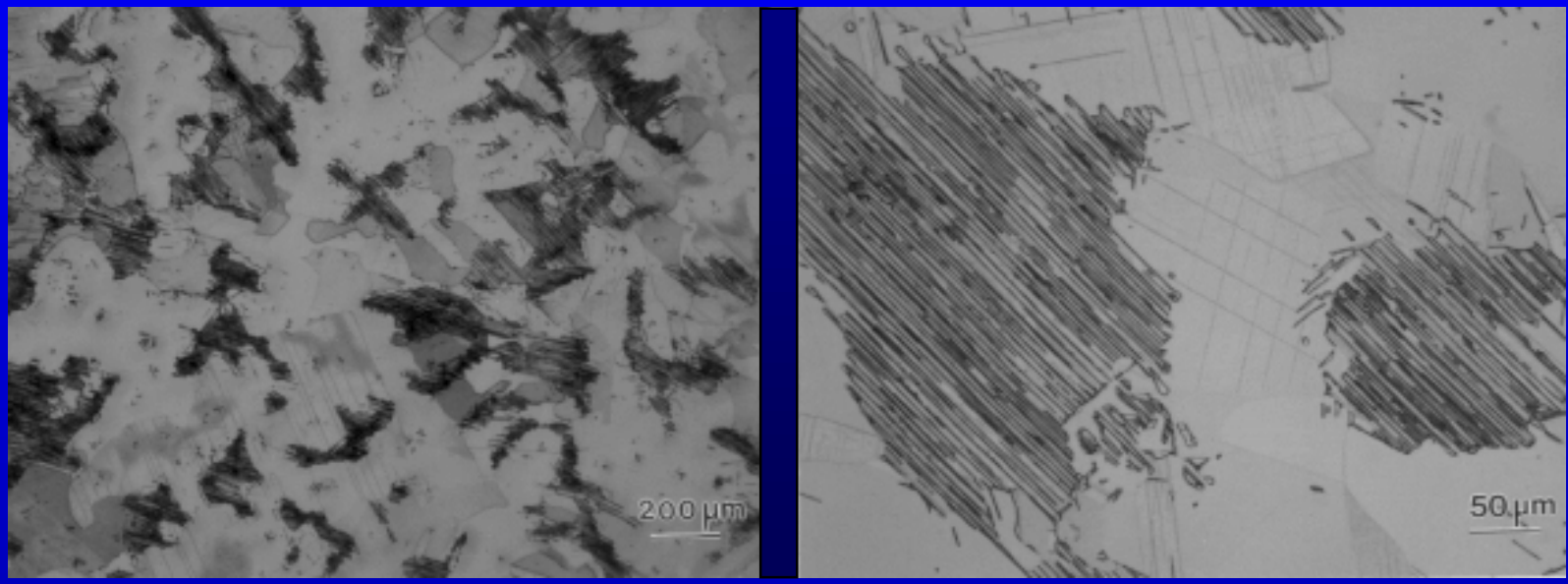
Cast & hot isostatically pressed Ti-48Al-2Cr-2Nb (Ti-48-2-2) showing a duplex microstructure

Conditions

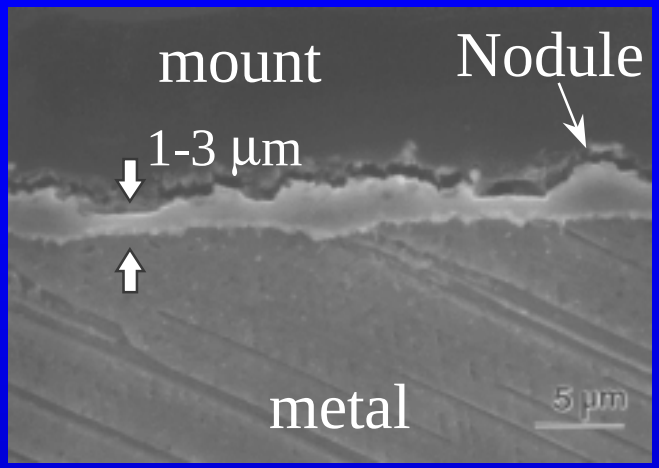
Samples were cut with a SiC wafering blade 3 cm x 1 cm^2 coupons and exposed to 704 ºC in air for times up to 9000 h

SEM, X-ray, EPMA (WDS)

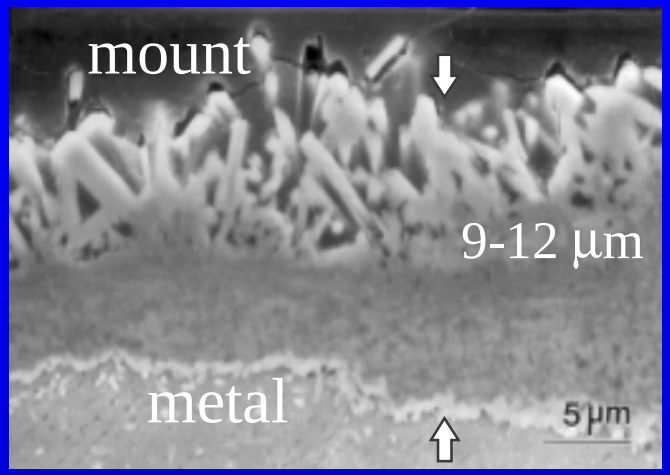
Ti-48-2-2 Alloy Showing Duplex Microstructure (γ –grains and lamellar $\gamma+\alpha_2$)



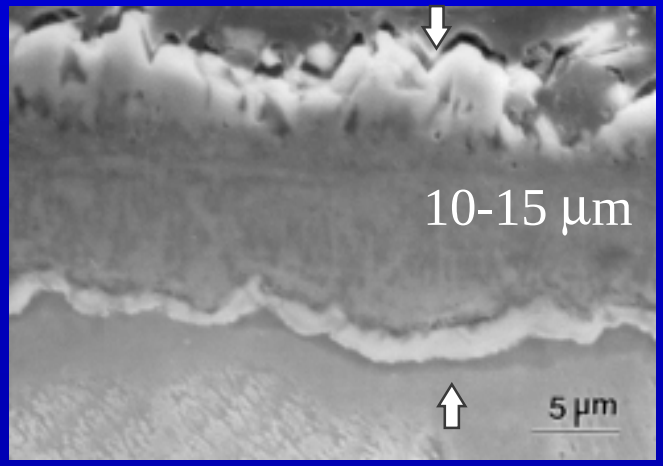
Overview of Scale Thickness on Ti-48-2-2 after Exposure in Air at 704ºC for Indicated Times



1000 h

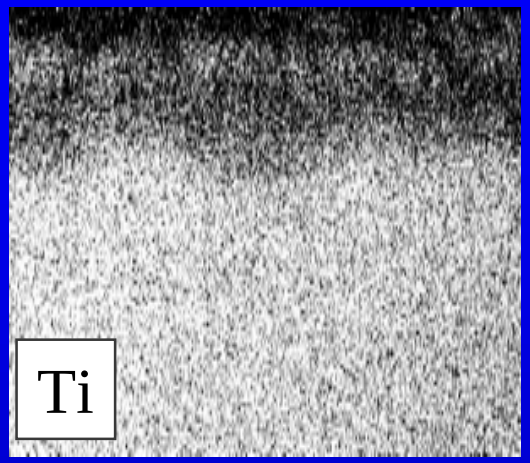


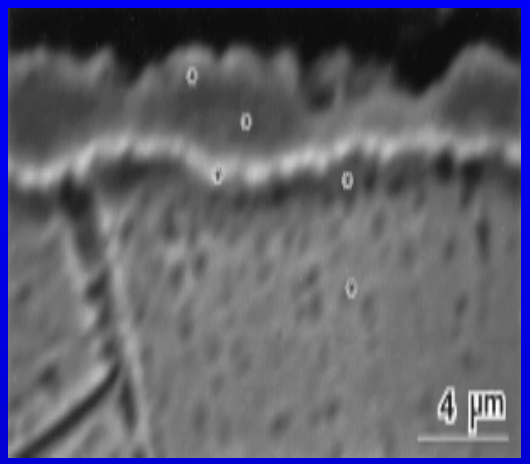
6000 h

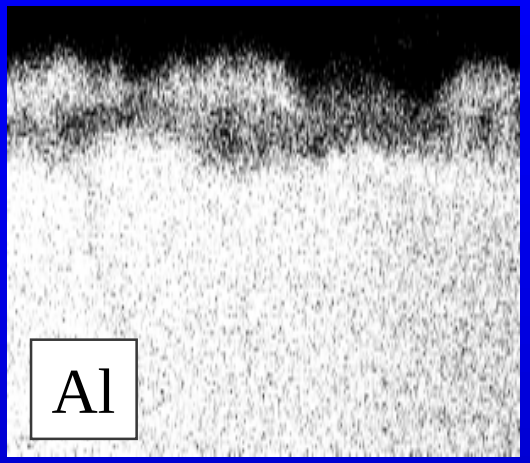


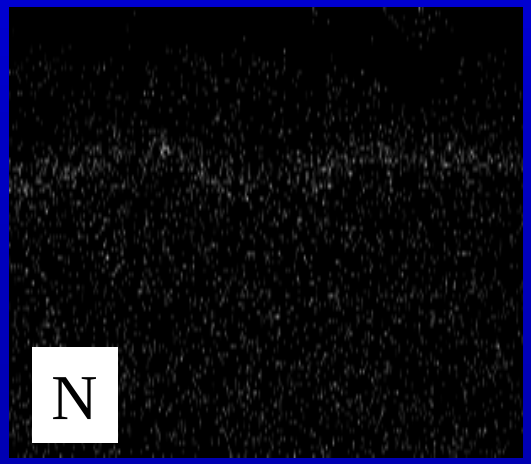
9000 h

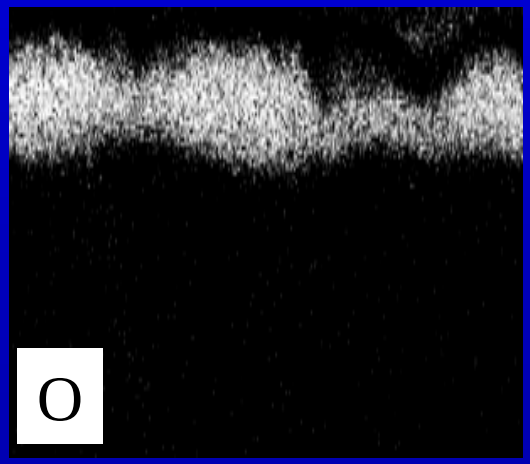
Microprobe Maps: Ti-48-2-2 after Exposure in Air at 704ºC for 1000 hours



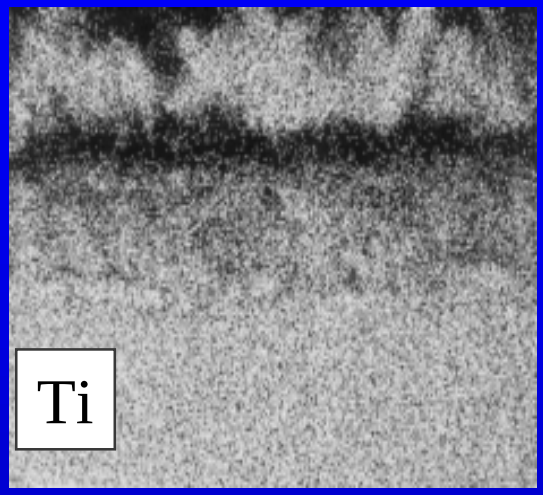


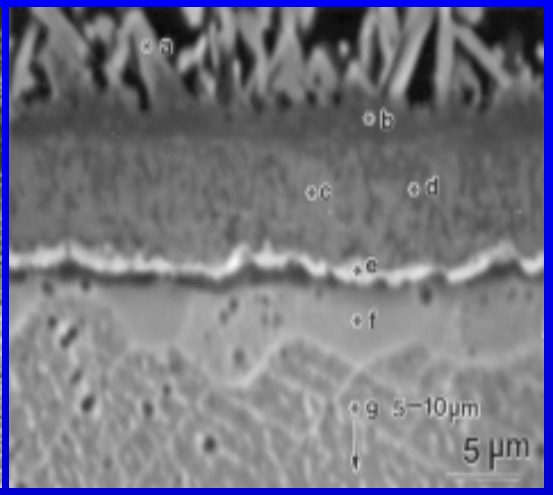


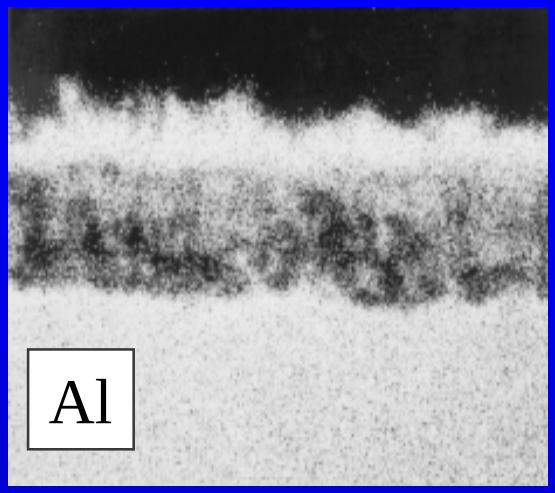


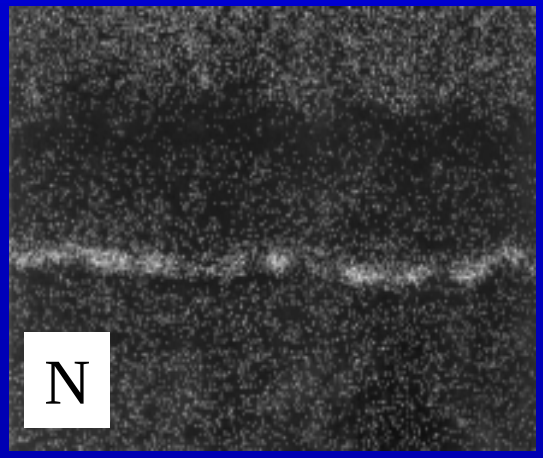


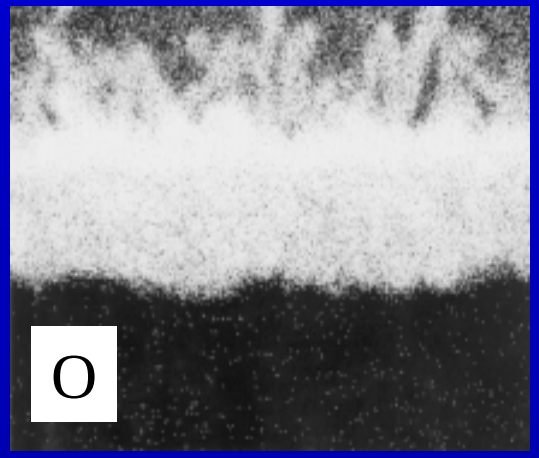
Microprobe Maps: Ti-48-2-2 after Exposure in Air at 704°C for 6000 hours



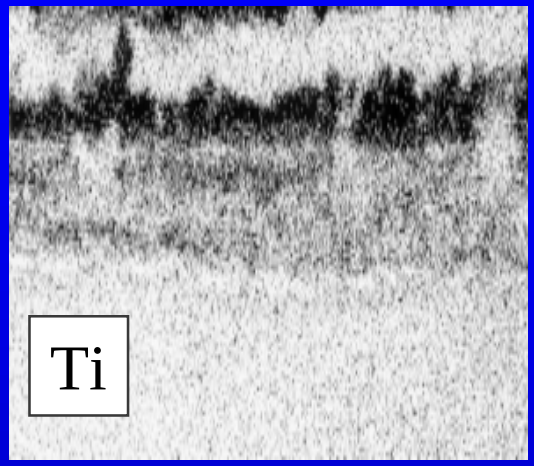


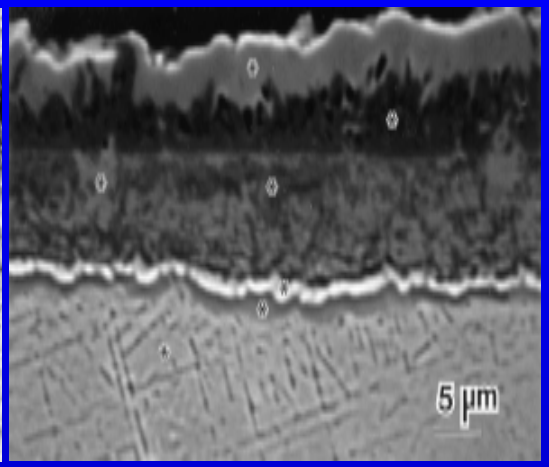


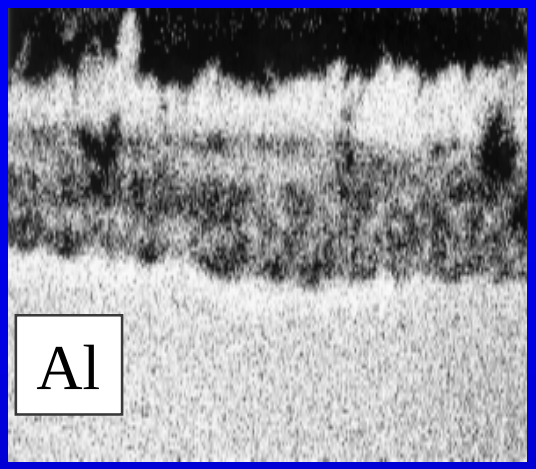


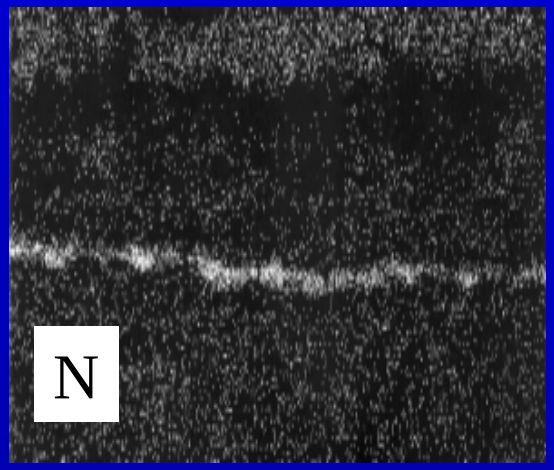


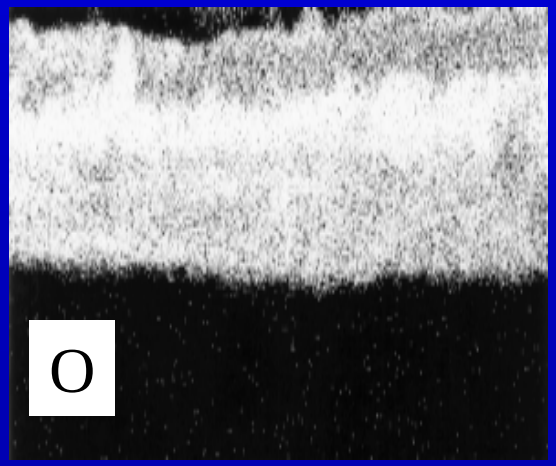
Microprobe Maps: Ti-48-2-2 after Exposure in Air at 704°C for 9000 hours



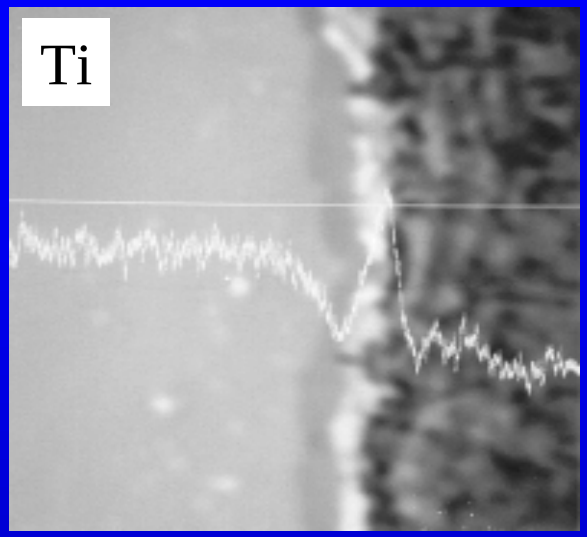


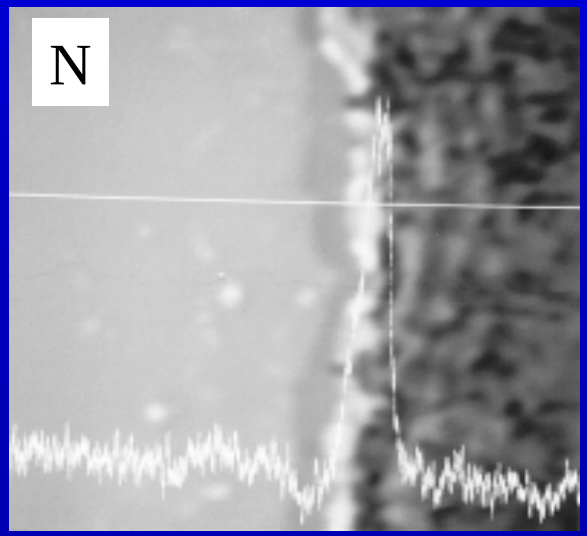


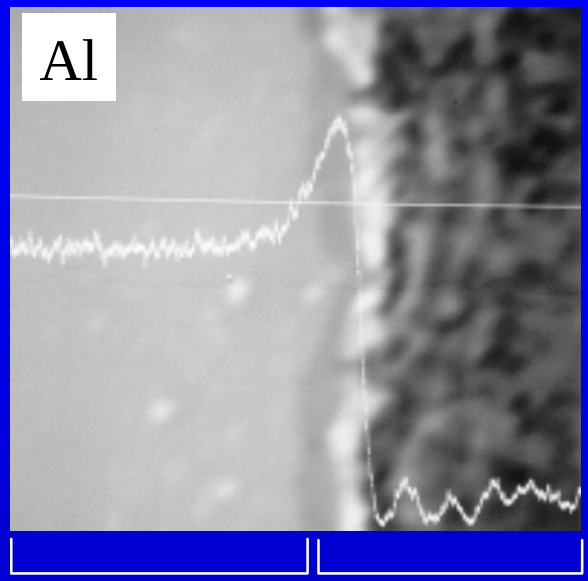




Microprobe Line Scan: Ti-48-2-2 after Exposure in Air at 704ºC for 9,000 hours



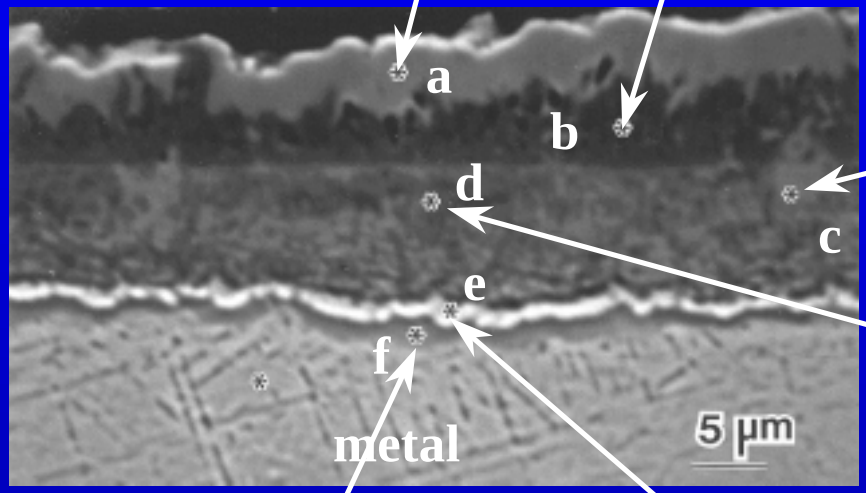




Compositional Microprobe Analyses (at.%)
Ti-48Al-2Cr-2Nb - 704 ºC - 9000 h in air

a 32.7 Ti - 0.3 Al - 66.7 O - 0.03 Cr - 0.005 Nb

b 2.7 Ti - 37.4 Al - 59.8 O - 0.1 Cr - 0 Nb



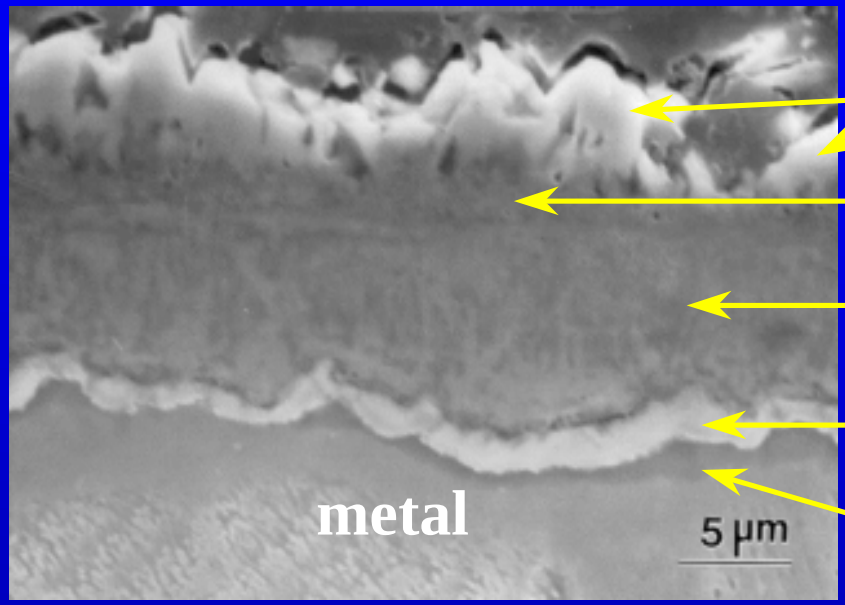
c 30.9 Ti - 2.6 Al - 63.9 O
1.3 Cr - 1.3 Nb

d 9.8 Ti - 28.9 Al -59.9 O
0.75 Cr - 0.6 Nb

e 46.8 Ti - 8.6 Al - 1.0 O - 1.3 Cr - 1 Nb - 41.2 N

f 34.9 Ti - 61.2 Al - 0 O - 1.7 Cr - 2.1 Nb - 0.2 N

Summary of Oxides, Nitride and Phase Observed in Ti-48Al-2Cr-2Nb after 9000 h at 704 °C in Air



TiO_2

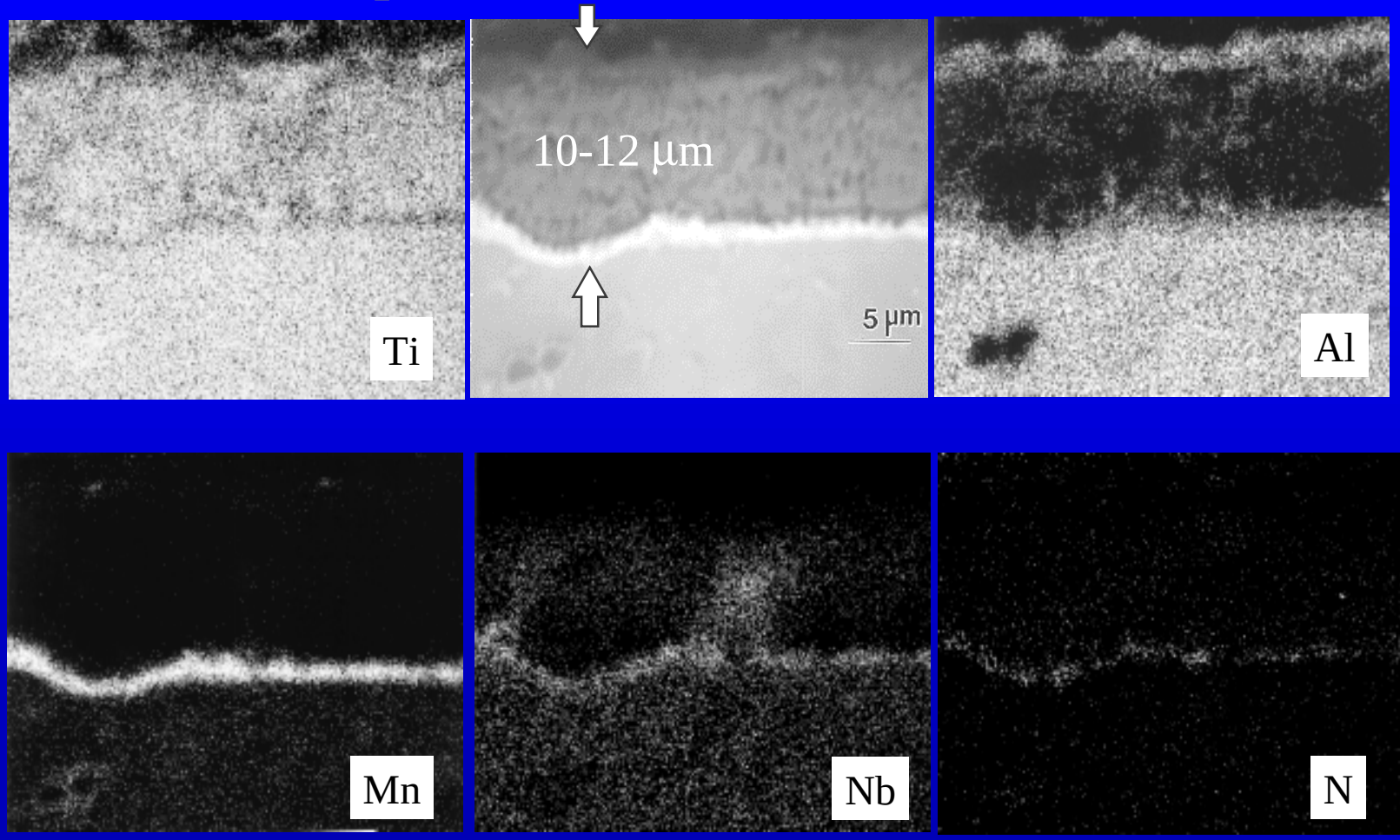
Al_2O_3

intermixed Al_2O_3+TiO_2

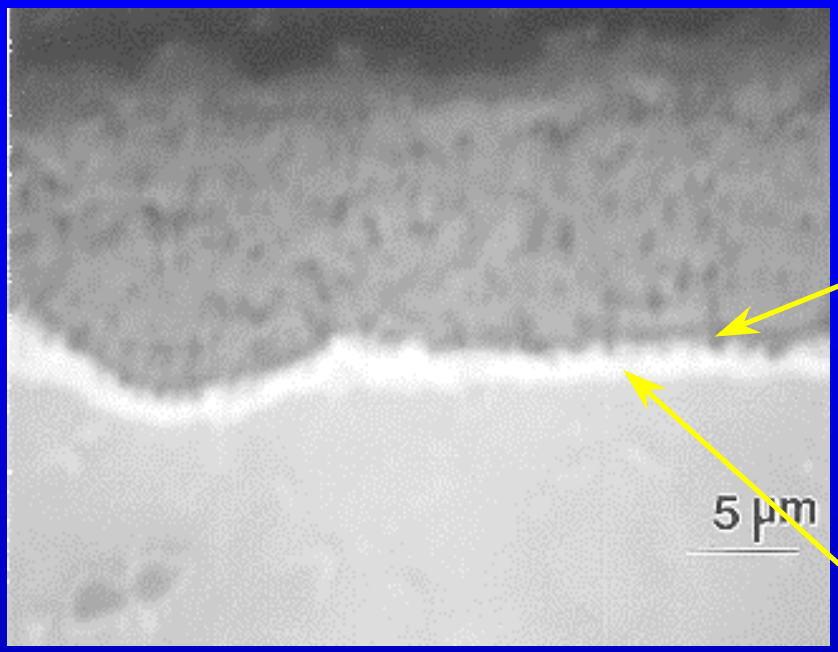
TiN

$TiAl_2$

Microprobe Maps: XD -Ti-48Al-2Mn-2Nb after Exposure in Air at 704 ºC for 11,000 h



Compositional Microprobe Analyses (at.%)
XD -Ti-48Al-2Mn-2Nb - 704 ºC -11,000 h in air

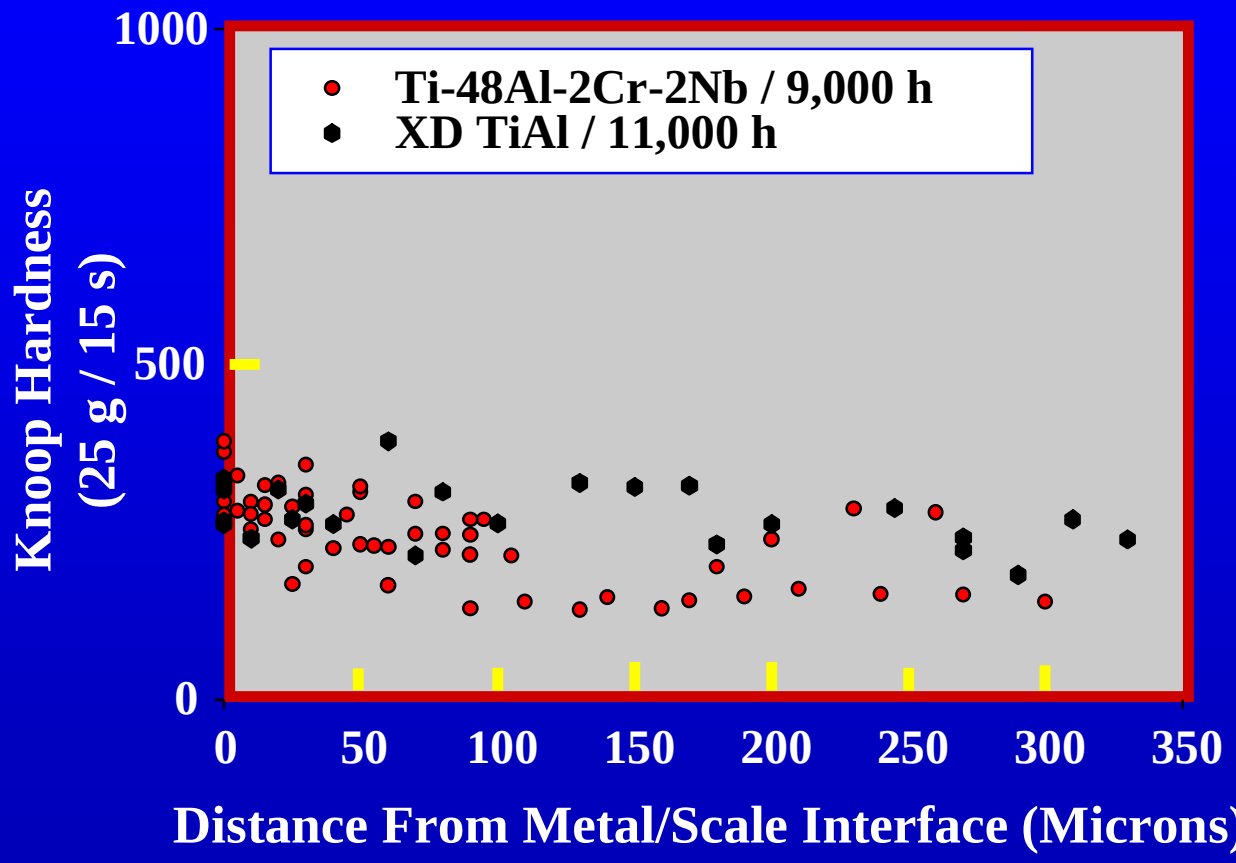


25.5 Ti - 12.4 Al - 1.4 Mn
1.26 Nb - 46.3 O - 13 N

31.7 Ti - 26.8 Al - 12.4 Mn
3.8 Nb - 10.6 O - 14.7 N

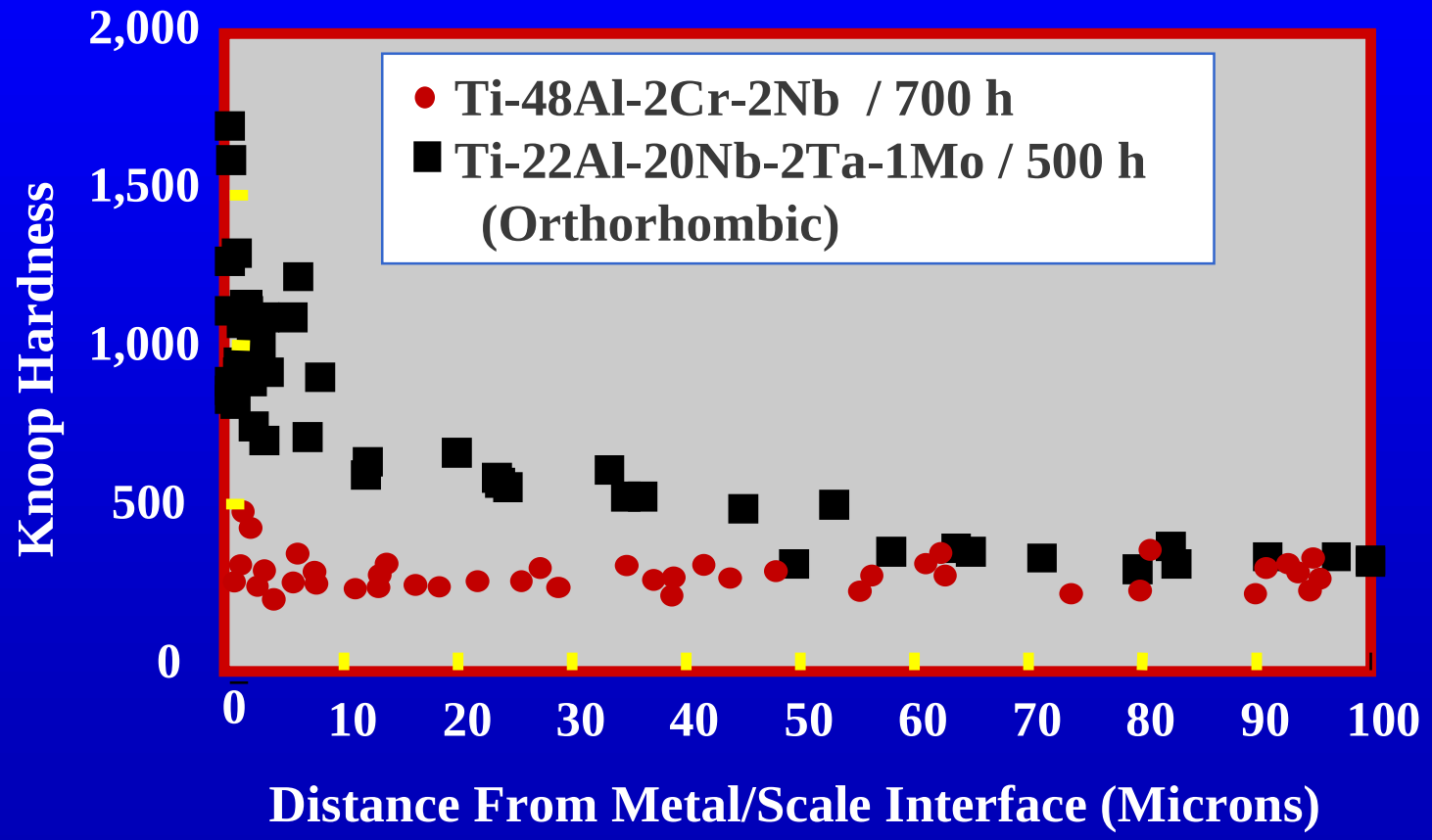
- Beam overlap
- No Al-rich phase

Knoop Microhardness Data as a Function of Distance from the Metal/Scale Interface - 704 °C - in Air



Technique only sensitive to within 5 μm of scale

Knoop Microhardness Data as a Function of Distance from the Metal/Scale Interface - 800 ºC - in Air



Source W. J. Brindley, 1994

Summary

- **Are γ-alloys sufficiently oxidation resistant at realistic use temperatures (i.e. ~700 ºC) for long term exposures?**
  Yes, Only a 15 μm thick scale formed on Ti-48Al-2Cr-2Nb after 9000 h and 12 μm for XD-TiAl after 11,000 h.

- **What type of scales are formed at these temperatures?**
  - Intermixed Al_2O_3/TiO_2 outer scale
  - Nitride Formation at middle scale interface

- **Is there substantial interstitial penetration (O, N) as in the case of α_2 - orthorhombic alloys?**
  No

Future Work

Long term exposure at 704 °C in air of γ–TiAl, TiAl-2Cr, TiAl-2Nb alloys to understand the role of alloying elements in the scale formation.

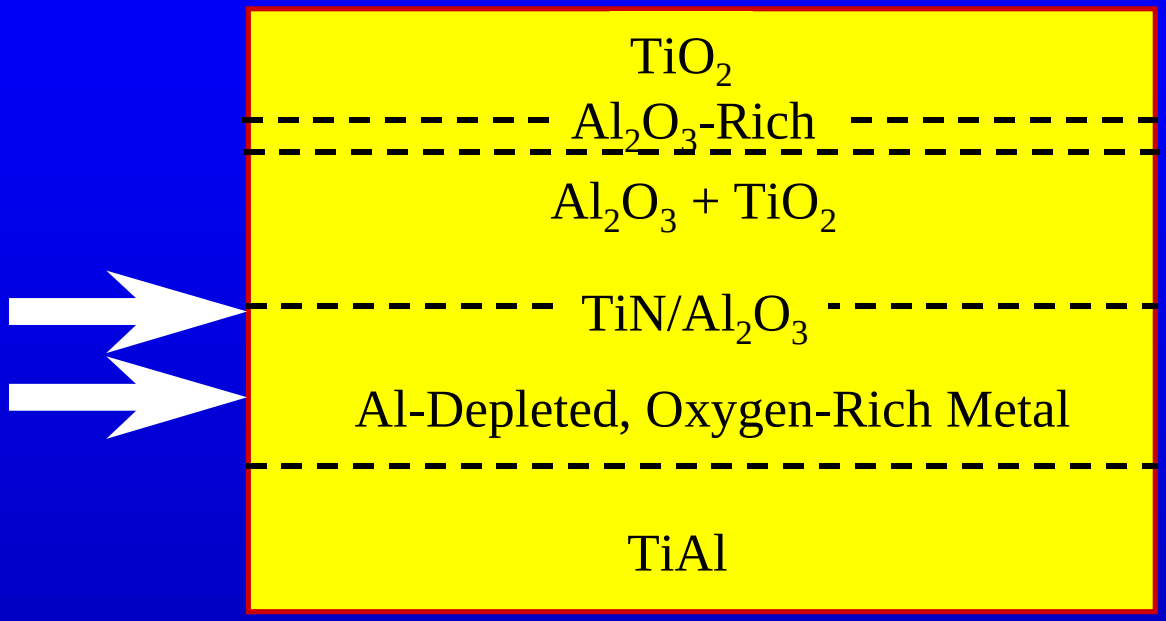
Concerns

- **Environmental Degradation of Fatigue Life (?)**
  - Nitride Formation / Compositional Changes at Metal Scale Interface
  - Local Interstitial Oxygen /Nitrogen Embrittlement

Schematic Binary TiAl Oxidized X-Section

(Based on Rahmel et al. 1995, Dettenwanger et al. 1996)

Binary TiAl, 900-1000°C, < 500 Hours, Air



Differences With Current Study on Ti-48Al-2Cr-2Nb, 704°C, >1000 Hours

- Composition (Cr+Nb) or Temperature/Time?